Plant Responses and Characteristics Associated with Dollar Spot Resistance in Creeping Bentgrass

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ABSTRACT

Dollar spot, incited by *Sclerotinia homoeocarpa* F.T. Bennett, is one of the most important diseases affecting creeping bentgrass (*Agrostis stolonifera* L.) golf greens, fairways, and tees. Genetic resistance to dollar spot is a promising control strategy. A study was initiated to: (i) evaluate dollar spot resistance of 265 collections of creeping bentgrass in two locations; (ii) determine bentgrass clone stability of dollar spot resistance; and (iii) evaluate 10 resistant and susceptible clones for disease, turf, and leaf traits. The field experiments were arranged in randomized complete blocks with six and five clonally propagated replicates in each of two locations evaluated across 2 yr in North Brunswick, NJ. Five isolates of *S. homoeocarpa* were used to inoculate the field experiments. New Jersey fairway collections had the highest percentage of stable dollar spot resistant clones compared with Illinois fairway and New Jersey and New York golf green collections in this particular study. Resistant clones maintained a significantly higher turf density and percentage green turf cover and smaller dollar spot diameter sizes compared with susceptible clones.

Dollar spot is a major disease that affects the performance of creeping bentgrass on golf greens, tees, and fairways. More than 70% of fungicides used on golf courses are used to control dollar spot, brown patch (*Rhizoctonia solani* Kuhn.), and anthracnose [*Colletotrichum graminicola* (Ces.) G.W. Wils.] diseases (Meritz Marketing Research, Inc., St. Louis, MO). The high cost of fungicides and the desire for high quality, aesthetically pleasing turf constitutes the need for genetic resistance to dollar spot disease in creeping bentgrass.

Many of the control strategies currently available are not completely effective for dollar spot disease suppression. Fungicide resistant isolates of *S. homoeocarpa* have developed from the intense and frequent use of fungicides (Burpee, 1997). As more resistant strains of the fungus develop (Cole et al., 1968, 1974; Golembiewski et al., 1995; Nicholson et al., 1971), fewer fungicides will be available to control dollar spot on creeping bentgrass. Cultural practices (Couch and Bloom, 1960; Halisky et al., 1981; Smith et al., 1989; Williams et al., 1996) and biocontrol agents (Goodman and Burpee, 1991; Lo et al., 1996; Nelson and Craft, 1992), although effective in reducing the level of dollar spot disease, do not completely control the disease and, therefore, have not been widely accepted as control measures.

One promising control strategy is genetic resistance of the host plant. Disease resistance is an important component of any breeding program, and through selection and breeding, improved turfgrass varieties can be developed. Creeping bentgrass cultivar development involves continuous cycles of recurrent selection for particular traits. However, the selection of environmentally unstable plants as parents for a recurrent selection cycle may slow breeding progress (Comstock and Moll, 1963). If stability of performance or the ability to show a minimum interaction with the environment is a genetic characteristic, then preliminary evaluation could be planned to identify stable genotypes (Eberhart and Russell, 1966). With only the more stable genotypes remaining for the final stage of testing, the breeder would be greatly aided in the selection of superior genotypes (Eberhart and Russell, 1966).

Disease resistance mechanisms including dollar spot resistance are not currently understood in turfgrasses. In tall fescue (*Festuca arundinacea* Schreb.), dense- vs. open-canopy microenvironments resulted in differential symptoms to brown patch disease, *Rhizoctonia solani* Kühn. (Giesler et al., 1996). Interblade hyphal growth of *R. solani* occurred more frequently in more dense canopies of tall fescue, apparently because of closer proximity of leaf blades. Canopy density appeared to be one of the factors involved in greater susceptibility of the dense cultivar 'Mohave' to *R. solani* compared with the more open cultivar 'KY-31' (Green and Burpee, 1997). 'Mustang' tall fescue, an improved turf-type cultivar with higher density, was also more susceptible to dollar spot than the common-type cultivar KY-31 (Brede, 1991).

Other plant characteristics such as stomates and trichomes could also play a role in disease resistance or susceptibility. Some fungal pathogens enter the plant through stomates (Agrios, 1997, p. 46, 135–137). *Sclerotinia homoeocarpa* reportedly gains entry into the plant via cut leaf tips and through stomates (Smiley et al., 1983, p. 14). A larger number of stomates could increase the chances of pathogen infection. Larger trichomes may play a role as a structural defense against the pathogen to prevent mycelial penetration and infection. Shaik (1985) identified a relationship between adult plant resistance to rust [*Uromyces appendiculatus* (Pers.:Pers.) Unger] and leaf pubescence in common bean (*Phaseolus vulgaris* L.). He stated that the reduced intensity [of disease] was attributed to the physical presence of long, straight trichomes on the abaxial surface of the upper leaves (Shaik, 1985).

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Abbreviations: LSV, least significant value.

The mechanisms of dollar spot resistance in creeping bentgrass have not been evaluated. Plant characteristics and their association with dollar spot resistance in creeping bentgrass are unknown. Understanding plant response to dollar spot disease and the identification of mechanisms involved in dollar spot resistance could improve the efficiency of selection for resistance to this disease.

The objectives of this study were to: (i) evaluate dollar spot disease resistance of 265 collections of creeping bentgrass in two locations; (ii) determine bentgrass clone stability of dollar spot resistance; and (iii) evaluate 10 resistant and susceptible clones for percentage green turf cover, dollar spot diameter size, turf density, stomate density, and trichome number and size to determine if any of these characteristics are associated with disease resistance.

MATERIALS AND METHODS

Field Experiments

Two experiments were established at the turfgrass research facility in North Brunswick, NJ, on a Nixon loam (fine-loamy, mixed, mesic Typic Hapludult) in the spring of 1998, as previously described by Bonos et al. (2003). One site was located on a plateau with a row of oak trees to the southern side (upper site). The other location (200 m from the first) was approximately 4.5 m lower in elevation, bordered on the eastern side by a row of trees, and wood line on the southern side (lower site). Two hundred and sixty-five creeping bentgrass clones were arranged in a randomized complete block with six clonally propagated replications in the upper site and five replications in the lower site. The creeping bentgrass clones were collected from old golf courses in New Jersey, eastern New York, Illinois, and Arizona. Randomly selected plants of three standard cultivars 'L-93' (dollar spot resistant), 'Crenshaw' (dollar spot susceptible), and 'Penncross' (moderately resistant) were also included (Bonos et al., 2003). Both field experiments were maintained at fairway cutting heights (1.3 cm = upper site, 1.7 cm = lower site).

Creeping bentgrass clones were inoculated with five isolates of *S. homoeocarpa* on 24 June 1998 and evaluated for disease resistance during 1998 and 1999 as described by Bonos et al. (2003). Dollar spot symptoms appeared 2 wk following inoculation, and plants were rated every week for a total of 13 wk during the growing season on a 1-to-9 scale: 9 = 0 to 5% diseased turf, 8 = 10% diseased turf, 7 = 15 to 25% diseased turf, 6 = 30 to 40% diseased turf, 5 = 40 to 50% diseased turf, 4 = 60 to 70% diseased turf, 3 = 75 to 85% diseased turf, 2 = 90% diseased turf, and 1 = 95 to 100% diseased turf.

Disease Assessment

Ten resistant (dollar spot rating >6.0) and 10 susceptible (dollar spot rating <3.0) clones were identified based on disease ratings during the 1998 growing season. Turf density ratings, percentage green turf cover, and dollar spot diameters were measured on four replicates of these clones in both locations during the 1999 growing season. Turf density was rated on a 1-to-9 scale with 9 representing highest density. Percentage green turf cover was visually estimated weekly as a percentage of green healthy turf of each bentgrass clone compared with diseased, dying, or dead turf. Dollar spot diameters were also measured weekly in centimeters on three dollar spots per bentgrass clone for 10 wk.

Plant Characteristics

Plant characteristics such as stomate density, trichome number, and trichome size, for most cases, were measured on the same 10 resistant and 10 susceptible clones; however, in some cases susceptible clones were replaced with other susceptible clones because of death from dollar spot. All characteristics were collected from fresh plant material taken directly from the field experiments. Acetate peels, 0.5 cm in length, were made of the underside of the second youngest turfgrass leaf following the procedure described by White et al. (1996). Three leaves per clone were evaluated. Stomates were counted under 200× magnification. All stomates were counted within the field of view of the microscope and then converted to stomate density. Trichome number and length were taken on only five resistant and five susceptible clones because of the lack of healthy leaf tissue of susceptible clones. Trichomes were counted along the leaf margin of the turfgrass leaf. Trichome length was measured on three randomly selected, previously counted trichomes per leaf. The leaf margin was chosen because of the improved visibility of trichome morphology at this location.

Statistical Analysis

Dollar spot disease data was subject to ANOVA with a split-plot in time model (Bonos et al., 2003; Steel et al., 1997). Dollar spot disease data was based on mean ratings across 13 wk per year. Creeping bentgrass clone stability analysis was conducted to determine the response of individual clones (genotypes) within a particular environment. This procedure was conducted analogous to that of Casler et al. (2001). Each location in a given year was considered as an individual environment. Clone means were computed for each environment. Each clone mean was converted into a deviation from the location mean by computing $x_{ij} = X_{ij} - M_{.j.}$, where X_{ij} = the observation on the ith population at the jth location and $M_{.j.}$ = mean of the jth location (Casler et al., 2001). The least significant value (LSV) for $\alpha = 0.05$ was computed using the formula $t_{\alpha/2},\text{dfe}\sqrt{[\text{MSe }(1/r + 1/rn)]}$, where dfe and MSe were determined from the error term of the ANOVA described in Bonos et al. (2003), r = number of reps, and n = total number of clones in the analysis. Positive values indicated that a clone had a higher-than-average dollar spot rating, negative values indicated that a clone had a lower-than-average dollar spot rating, and values near zero indicated that a clone was near the mean for that location (Casler et al., 2001). A stable clone was defined as a particular clone with all four deviations from location-year means significantly greater than (stable resistant) or less than (stable susceptible) the LSV for each environment.

Turf density, percentage green turf cover, dollar spot diameter, stomate density, and trichome number and length were subject to ANOVA by location. Orthogonal contrasts were used to compare susceptible and resistant clones. Phenotypic correlation coefficients were calculated to compare disease resistance ratings with plant characteristics for the mean of each clone.

RESULTS AND DISCUSSION

Stability Analysis

Of the 265 clones evaluated in the ANOVA, only 2% maintained significant dollar spot resistance with dollar spot disease average ratings ≥6.0 across both years and both locations. No clone was completely immune to dollar spot. Ninety-two of the 265 clones (34.7%) analyzed were stable across all environments, indicating these clones had a similar response to dollar spot disease in all four environments. The stability of these clones across all environments indicates that there is a strong genetic component involved in dollar spot disease resistance in these creeping bentgrass clones. The remaining 163 clones (73.3%) were unstable across all four environments, indicating these clones had different dollar spot disease responses depending on the environment. The high percentage of clones exhibiting unstable phenotypes across environments indicates that dollar spot disease development may not be under complete genetic control but is also dependent upon environmental conditions. This is typical of quantitatively inherited traits, supporting the idea that dollar spot disease is quantitatively inherited (Bonos et al., 2003; Poehlman and Sleper, 1995, p. 71–75.).

Forty of the 92 (43.5%) stable clones were stable resistant, with dollar spot ratings that were significantly greater than the average of the environment mean for all four environments. Means for 10 of these clones are illustrated in Table 1. The remaining 52 stable clones (57.5%) were stable susceptible, with below-average dollar spot ratings across all four environments (10 are illustrated in Table 1). The range among clone means, combined with the ability to identify stable resistant clones, indicates that progress can most likely be made in breeding creeping bentgrass cultivars for resistance to dollar spot. The lack of stability for the majority of clones and the highly variable disease reactions for unstable clones (Table 1) indicates that multiple-environment evaluations are essential for identifying superior clones before selection and breeding.

All collection sites had higher percentages of stable susceptible clones compared with stable resistant clones, except for New Jersey fairway collections, which had a four-fold greater frequency of stable resistant than stable susceptible clones (Table 2). Interestingly, NJ fairway collections had the highest percentage of stable resistant clones (27%), while the NJ putting green collections had one of the lowest percentages of stable resistant clones (5%) and the highest percentage of stable susceptible clones (33%) (Table 2).

Golf course fairways are typically sprayed with fungicides less frequently than golf greens, because of the greater cost associated with the larger fairway area and a higher aesthetic tolerance for some disease in the

Table 1. Stability of creeping bentgrass clone responses to dollar spot disease across two locations and 2 yr in experiments established in the spring of 1998 at North Brunswick, NJ.

						Deviations from location-yr mean			
						Upper		Lower	
Clone no.†	Identification	Stability‡	State	Collection site§	Dollar spot avg.¶	Yr 1	Yr 2	Yr 1	Yr 2
1	Penncross C2	R stable	NJ	fwy	6.7	1.97	2.85	2.86	4.22
2	L93-10	R stable		unkn	7.2	2.00	3.16	3.58	5.17
3	C 6-5	R stable		unkn	6.8	3.33	2.84	2.47	3.42
4	Az-144	R stable	AZ	green	6.2	1.44	3.05	1.92	3.54
5	7349-5 White Beeches	R stable	NJ	unkn	6.2	2.24	1.61	2.36	3.55
6	7373-5 Echo Lake	R stable	NJ	fwy	6.1	1.79	2.59	2.34	2.92
7	7342-2 Rumson	R stable	NJ	fwy	6.6	2.43	2.12	2.71	4.07
8	7359-3 Hollywood	R stable	NJ	fwy	7.6	4.30	2.85	3.56	4.90
9	7356-5 Hollywood	R stable	NJ	fwy	7.1	2.65	2.37	3.40	5.14
10	7361-5 Fort Monmouth	R stable	NJ	fwy	7.2	3.30	2.69	3.26	2.98
11	7362-5 Suburban	unstable	NJ	fwy	5.0	0.44	0.89	1.62	2.08
12	Az-145	unstable	AZ	green	4.7	0.80	0.14	0.72	2.34
13	7450-1 Harkers Hollow	unstable	NJ	green	4.8	1.67	2.27	0.24	−0.38
14	H96-363 BT	unstable	IL	fwy	3.8	0.12	−0.05	0.00	0.32
15	7453-2 Old West	unstable	NY	green	3.8	−0.35	0.07	0.56	−0.24
16	7352-5 Piping Rock	unstable	NY	fwy	3.6	−0.08	−0.26	0.02	−0.38
17	H96-409 BT	unstable	IL	fwy	3.0	−0.91	−0.61	−0.34	−1.22
18	7436-1 Rumson	unstable	NJ	green	3.0	−1.25	0.34	−1.36	−0.94
19	Az-25	unstable	AZ	unkn	2.9	−0.98	−0.50	−0.66	−1.40
20	7340-3 Rumson	unstable	NJ	fwy	2.6	−0.83	−2.55	0.30	−1.34
21	7424-5 Pine Hollow	S stable	NY	green	1.9	−1.60	−2.03	−2.08	−1.74
22	7411-4 Piping Rock	S stable	NY	green	1.6	−1.70	−3.02	−1.99	−1.70
23	AZ-83	S stable	AZ	unkn	2.1	−1.91	−1.04	−1.85	−1.86
24	7418-3 Piping Rock	S stable	NY	green	2.6	−1.11	−1.21	−1.21	−1.23
25	7442-3 Deal	S stable	NJ	green	2.0	−1.41	−2.45	−1.42	−1.84
26	Crenshaw-5	S stable		unkn	3.8	−1.61	−2.69	−1.48	−1.67
27	7369-1 Canoe Brook	S stable	NJ	unkn	2.0	−1.86	−1.68	−1.66	−1.70
28	7434-6 Spring Lake	S stable	NJ	green	1.8	−2.05	−2.26	−1.48	−1.86
29	7366-6 Canoe Brook	S stable	NJ	unkn	2.4	−1.53	−1.66	−1.00	−1.00
30	7331-2 Manasquan River	S stable	NJ	fwy	2.3	−1.18	−1.51	−1.42	−1.70
LSD (0.05) or LSV (0.05)#					0.6	0.61	0.61	0.67	0.67

† Because of space restrictions, only 10 clones representing stable resistant, unstable, and stable susceptible classes are presented. Complete data set is available upon request.

‡ R stable = indicates clones were stable resistant across all environments, S stable = indicates clones were stable susceptible across all environments. Stability was assigned to a particular clone if all four deviations from location-year means were significantly greater or less than the LSV ($P < 0.05$) within each environment.

§ All samples were collected on golf courses; fwy = fairway collection, green = putting green collection; unkn = unknown site.

¶ Dollar spot average rating across all locations and years, 1–9 rating scale, 9 = 0–5% dollar spot diseased turf, 8 = 10% diseased turf, 7 = 15–25% diseased turf, 6 = 30–40% diseased turf, 5 = 40–50% diseased turf, 4 = 60–70% diseased turf, 3 = 75–85% diseased turf, 2 = 90% diseased turf, and 1 = 95–100% diseased turf.

LSV = least significant value.

Table 2. Summary of stability analysis of creeping bentgrass clones collected from old golf courses in New Jersey, New York, Illinois and Arizona. Means were computed across six replicates, two locations and 2 yr.

State	Collection site	No. of clones	Stable resistant	Unstable	Stable susceptible
NJ	Fairway	63	17	42	4
NJ	Green	39	2	24	13
NY	Green	30	4	21	5
NY	Fairway	6	0	5	1
IL	Fairway	26	2	17	7
AZ	Unknown	50	8	32	10

fairways. This may cause greater selection pressure in the fairways for resistant genotypes, causing a shift in the population toward a higher frequency of resistant clones. Golf greens, on the other hand, are regularly sprayed with fungicides, reducing the potential for natural selection of resistant genotypes. Thus, natural selection pressures on New Jersey golf courses may be partly responsible for these observed results. They may also be due, in part, to evaluation under fairway conditions, favoring expression of dollar spot resistance of clones collected from fairways vs. greens, although this would only occur if there is a significant difference in dollar spot expression between the two turf types.

These hypotheses, however, do not explain the results found for New York or Illinois fairway collections, which had a higher percentage of stable susceptible clones. Dollar spot disease pressure may be lower on New York or Illinois golf courses, compared with New Jersey golf courses, because of the reduced inoculum load or the greater use of fungicides. Additionally, dollar spot isolates most likely vary among environments, and the New York and Illinois clones may not be resistant to the isolates collected from New Jersey for use in this study. These results indicate that selection and breeding of bentgrasses from New Jersey golf course fairway collections may be more effective for developing dollar spot resistant cultivars for New Jersey growing conditions. Creeping bentgrass cultivars are generally marketed on a nationwide basis in the USA, but these results suggest that there may be some reasons to consider either development and marketing of cultivars on a more regional basis, taking advantage of natural selection forces for resistance to regional inoculum sources or sufficient testing of regionally developed cultivars in diverse environments.

Plant Characteristics—Resistant vs. Susceptible Clones

Percentage Green Turf Cover and Dollar Spot Diameters

Resistant clones maintained a significantly higher percentage of green turf cover compared with susceptible clones in both the upper and lower locations (Fig. 1). Resistant clones also maintained significantly smaller dollar spot diameter sizes compared with susceptible clones in both the upper and lower locations (Fig. 2). Dollar spot diameters of susceptible clones continued to grow larger throughout the growing season and eventually covered the entire bentgrass clones as evidenced by the low percentage green turf cover of those plants

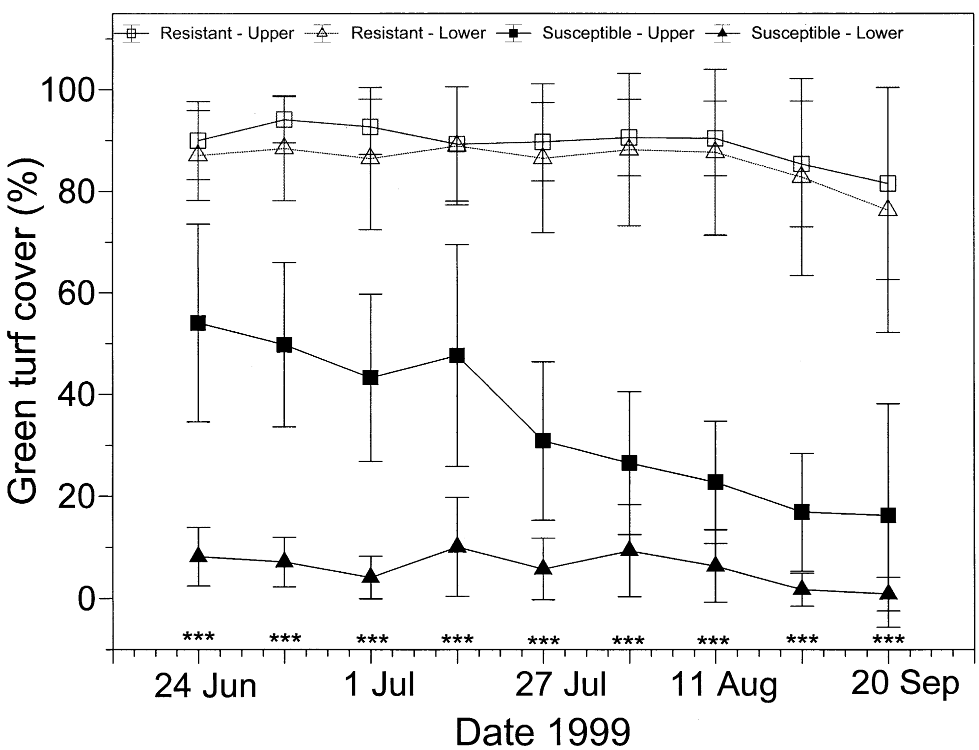

Fig. 1. Percentage green turf cover of creeping bentgrass clones in response to dollar spot evaluated at the upper location (square symbols) and the lower location (triangle symbols) in two field experiments established at North Brunswick, NJ. Data points represent means of 10 resistant (open symbols) and 10 susceptible (closed symbols) clones. Bars represent ±SD. * Denotes significant orthogonal contrast between resistant and susceptible clones at $P < 0.001$.**

(Fig. 1 and 2). Dollar spot diameters of resistant clones, on the other hand, remained small throughout the growing season (Fig. 2). The dollar spots of the resistant clones rarely coalesced to form large dollar spots (personal observation). The mechanism involved in dollar spot resistance is unknown, but this research indicates that resistant clones may inhibit fungal growth and development. Future studies should determine if resistant plants produce inhibitory chemicals, such as antifungal compounds.

Turf Density

Significant differences in turf density ratings were observed among creeping bentgrass clones (Table 3). Resistant clones had significantly higher turf densities compared with susceptible clones at both locations. This observation may have resulted from greater plant health of the less symptomatic, more resistant clones. Overall, there was no significant correlation of turfgrass density to dollar spot resistance ratings for either location (r = 0.13 and 0.29). Conversely, tall fescue cultivars with increased shoot density also have increased brown patch susceptibility (Brede, 1991; Giesler et al., 1996; Green and Burpee, 1997). This does not appear to be true for dollar spot resistance in creeping bentgrass.

Stomate Density

Significant differences in stomate density were observed among creeping bentgrass clones (Table 3). However, orthogonal contrasts between resistant and susceptible clones and the overall correlation between stomate density and dollar spot ratings were not significant. Thus, stomate density was not associated with dollar spot resistance in these creeping bentgrass clones.

Trichome Number and Size

Significant differences in trichome number were found among creeping bentgrass clones (Table 3). Although dollar spot resistant bentgrasses tended to have fewer trichomes than susceptible clones, this was only found to be significant for the lower location. Trichome number was not correlated with dollar spot resistance ratings for either location ($r = -0.19$ and -0.27).

Significant differences in trichome size were also found among creeping bentgrass clones (Table 3). Orthogonal contrasts between resistant and susceptible clones indicated that resistant clones had 42 to 64% larger trichomes than susceptible clones ($P < 0.01$ for both locations). Furthermore, there was some evidence for a positive correlation of trichome size to dollar spot resistance ratings for both upper ($r = 0.56$, $P < 0.1$) and lower ($r = 0.58$, $P < 0.1$) locations. Thus, trichome size may play a role in resistance of creeping bentgrass to the dollar spot fungus.

Adult-plant resistance to rust in common bean was attributable to the physical presence of long, straight trichomes on the abaxial surface of the upper leaves (Shaik, 1985). It is unknown whether turfgrass trichomes are glandular or contain high amounts of silica, which has been found to reduce disease in other plant species

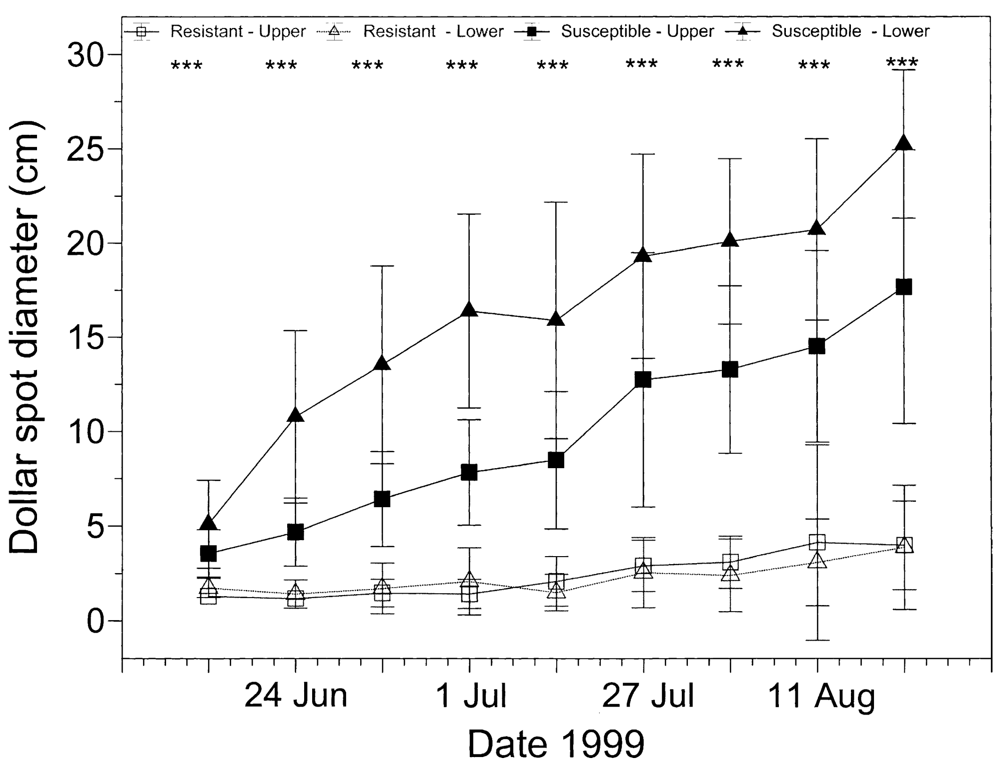

Fig. 2. Dollar spot diameters of creeping bentgrass clones evaluated at the upper location (square symbols) and the lower location (triangle symbols) in two field experiments established at North Brunswick, NJ. Data points represent means of 10 resistant (open symbols) and 10 susceptible (closed symbols) clones. Bars represent ±SD. * Denotes significant orthogonal contrast between resistant and susceptible clones at $P < 0.001$.**

Table 3. Dollar spot ratings, density ratings, stomate, density, trichome number, and length of dollar spot resistant and susceptible creeping bentgrass clones established in two field experiments (both upper and lower locations) in 1998 at North Brunswick, NJ.

Category and clone	Spot ratings		Density ratings		Stomate density†	Trichome no.§		Trichome length	
	Upper‡	Lower	Upper	Lower	Lower	Upper	Lower	Upper	Lower
	1–9 scale¶				mm^{-2}	cm^{-1}		μm	
Resistant									
PenncrossC-2	6.3	7.2	8.3	8.8	81.8	24	54	5.5	5.8
L93-10	6.4	8.1	8.0	7.7	70.7	48	56	5.3	5.9
C6-5	6.9	6.6	7.3	6.8	–	–	–	–	–
AZ-144	6.1	6.4	7.0	7.3	57.7	46	52	6.0	5.9
7349-5	5.6	6.1	6.8	8.0	–	–	–	–	–
7373-5	6.0	6.3	6.5	6.3	68.8	–	–	–	–
7342-2	6.1	7.8	3.5	2.5	73.5	–	–	–	–
7359-3	7.4	7.9	3.3	4.5	86.5	82	70	8.5	9.5
7361-5	6.9	7.6	2.0	3.5	–	50	56	15.9	10.4
7356-5	6.5	8.1	–	–	50.2	–	–	–	–
Mean	6.4	7.2	5.8	6.2	69.8	50	58	8.2	7.5
Susceptible									
7424-5	2.0	1.7	8.3	6.0	80.9	–	–	–	–
7411-4	1.5	1.8	8.0	5.7	66.0	–	–	–	–
AZ-83	2.4	1.8	6.0	5.3	–	–	–	–	–
7418-3	2.7	2.4	5.5	5.3	67.0	68	64	5.0	6.6
7442-3	1.9	2.0	4.0	4.0	–	–	–	–	–
Cren-5	1.7	2.1	3.8	4.8	75.3	50	62	4.6	4.6
7369-1	2.1	2.0	3.5	2.0	–	54	38	5.8	3.8
7434-6	1.7	2.0	3.3	5.3	62.3	–	–	–	–
7366-6	2.2	2.7	3.3	4.5	70.7	96	10	4.5	4.5
7331-2	2.5	2.1	–	–	117.2	38	80	5.1	7.1
Mean	2.1	2.1	5.1	4.8	77.2	62	70	5.0	5.3
LSD (0.05)	0.6	0.6	2.0	1.3	27.3	25	28	1.9	2.9
Contrast resistant vs. susceptible			*	***	ns#	ns	*	***	**
CV, %	22.9	21.5	22.3	15.3	21.3	25.4	25.1	15.7	26.7

* Significant at the 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
† Stomates were counted under 200× magnification. All stomates were counted within the field of view of the microscope and converted to stomate density.
‡ Both upper and lower sites established at North Brunswick, NJ, in spring of 1998. The upper site was on a high plateau, while the lower site was approximately 4.6 m lower in elevation.
§ Trichomes were counted only along the margin of the turfgrass leaf.
¶ 1–9 rating scale, 9 = 0–5% dollar spot diseased turf, 8 = 10% diseased turf, 7 = 15–25% diseased turf, 6 = 30–40% diseased turf, 5 = 40–50% diseased turf, 4 = 60–70% diseased turf, 3 = 75–85% diseased turf, 2 = 90% diseased turf, and 1 = 95–100% diseased turf.
# ns = not significant.

(Hamel and Heckman, 1999; Osuna-Canizalez et al., 1991; Samuels et al., 1991, 1993; Volk et al., 1958). Further research is required to increase our understanding of the role of trichomes in disease resistance and determine the specific resistance mechanism used by creeping bentgrasses that poses resistance to *S. homoeocarpa.*

CONCLUSIONS

This is the first study reporting specific creeping bentgrass clone responses to dollar spot disease. It is evident that creeping bentgrass clones differ in their stability of response to dollar spot disease. These particular collections of creeping bentgrass were quite susceptible to the isolates of the fungus used in the study, with only 2% of the population maintaining adequate dollar spot resistance during the 2-yr study. Stable clones with above-average dollar spot resistance can be found at higher concentrations on New Jersey fairways, at least for this particular study under these conditions.

Resistant clones maintain smaller lesion diameter sizes than susceptible clones, indicating that they are able to keep the fungus from spreading and limit the coalescing of spots; however, the actual mechanism for this phenomenon is not known. Trichome size seems to be associated with dollar spot resistance, with resistant clones having larger trichomes than susceptible clones regardless of turf density and trichome number. Large trichomes may result in the physical hindrance of the pathogen to infect the host. Identification of chitinases or other fungal-inhibiting chemicals that may be produced by the resistant clones may further clarify the role, if any, that trichomes play in regulating dollar spot disease resistance in creeping bentgrass.

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